Simulation of Flight Information Service – Broadcast on the ADS-B Candidate Links

Michael W. Castle

Chad Sprouse

Larry Bachman

Johns Hopkins Univ. Applied Physics Laboratory

and

Thomas E. Tanger – LMGT

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FIS-B and ADS-B

- Flight Information Services – Broadcast (FIS-B) is a set of information products that will be delivered to aircraft in flight
- Automatic Dependent Surveillance – Broadcast is “a function on an aircraft or surface vehicle that periodically broadcasts its state vector and other information”
- ADS-B Candidate Systems
  - VHF Data Link, Mode 4 (VDL Mode 4)
  - 1090 Mode-S Extended Squitter
  - Universal Access Transceiver (UAT)

Assumptions

- Time frame is 2007 for traffic load estimates
  - Traffic Scenario has 2103 aircraft in a 400 nmi radius around Los Angeles with 176 aircraft on the ground - mainly affects 1090 ES system
- Hexagonal grid of ground stations with 60 and 120 nmi inter-site spacings
- Receiver performance models for all three links based on bench-test measurements done at APL on each system's equipment

Assumptions (cont.)

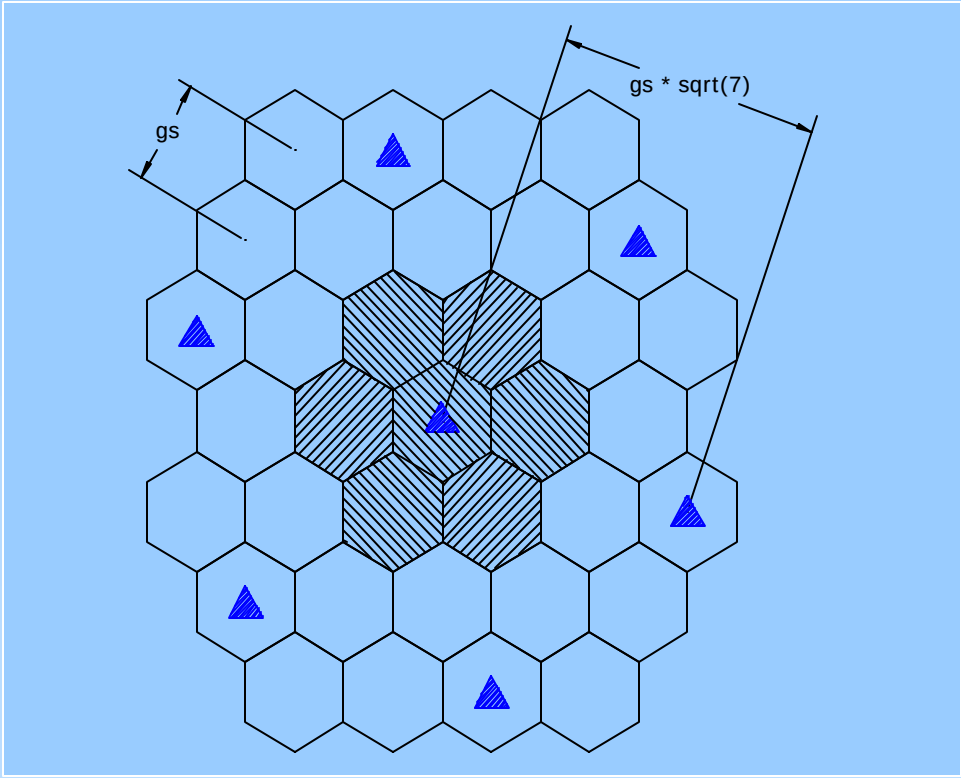
- Follow 4 representative receivers (ADS-B equipage and altitude varied)
  1. A0 receiver at 5,000 feet
  2. A1 receiver at 18,000 feet
  3. A2 receiver at 23,000 feet
  4. A3 receiver at 35,000 feet
- Metric – Ability to deliver the FIS-B product with 90% success rate (MSR) within the update requirements
- FIS-B Product Size is undetermined
  - Sizes of 5 kbit and 50 kbit used

Comparing the 3 Systems – Limitations

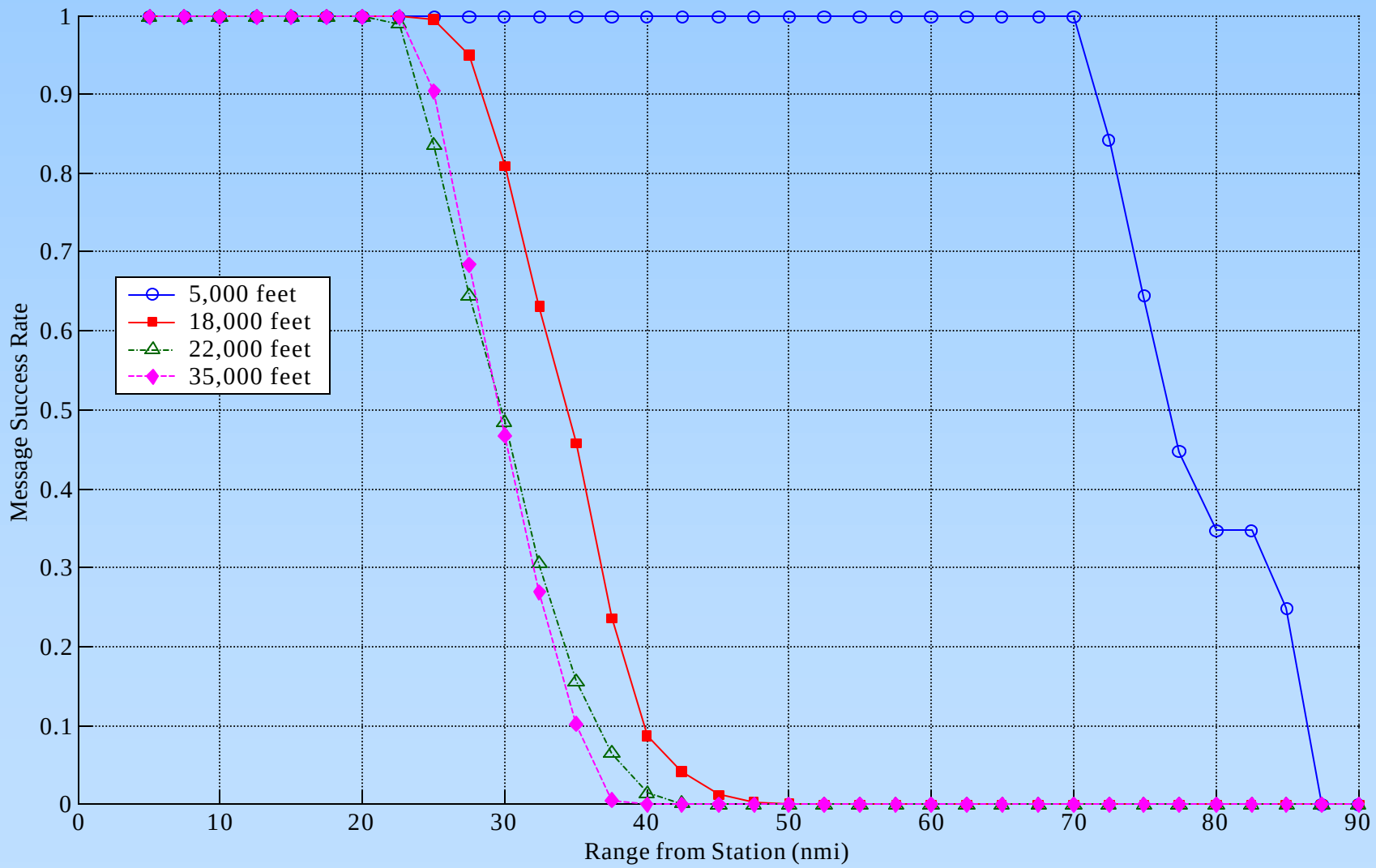
- Practical considerations will drive ground station locations - a uniform grid is an estimate for interference calculations
- GBT antenna patterns may affect things
- Each system has room to be optimized
- Performance trade-offs must be looked at between grid spacing, coverage, product size, and throughput

FIS-B on VDL Mode 4

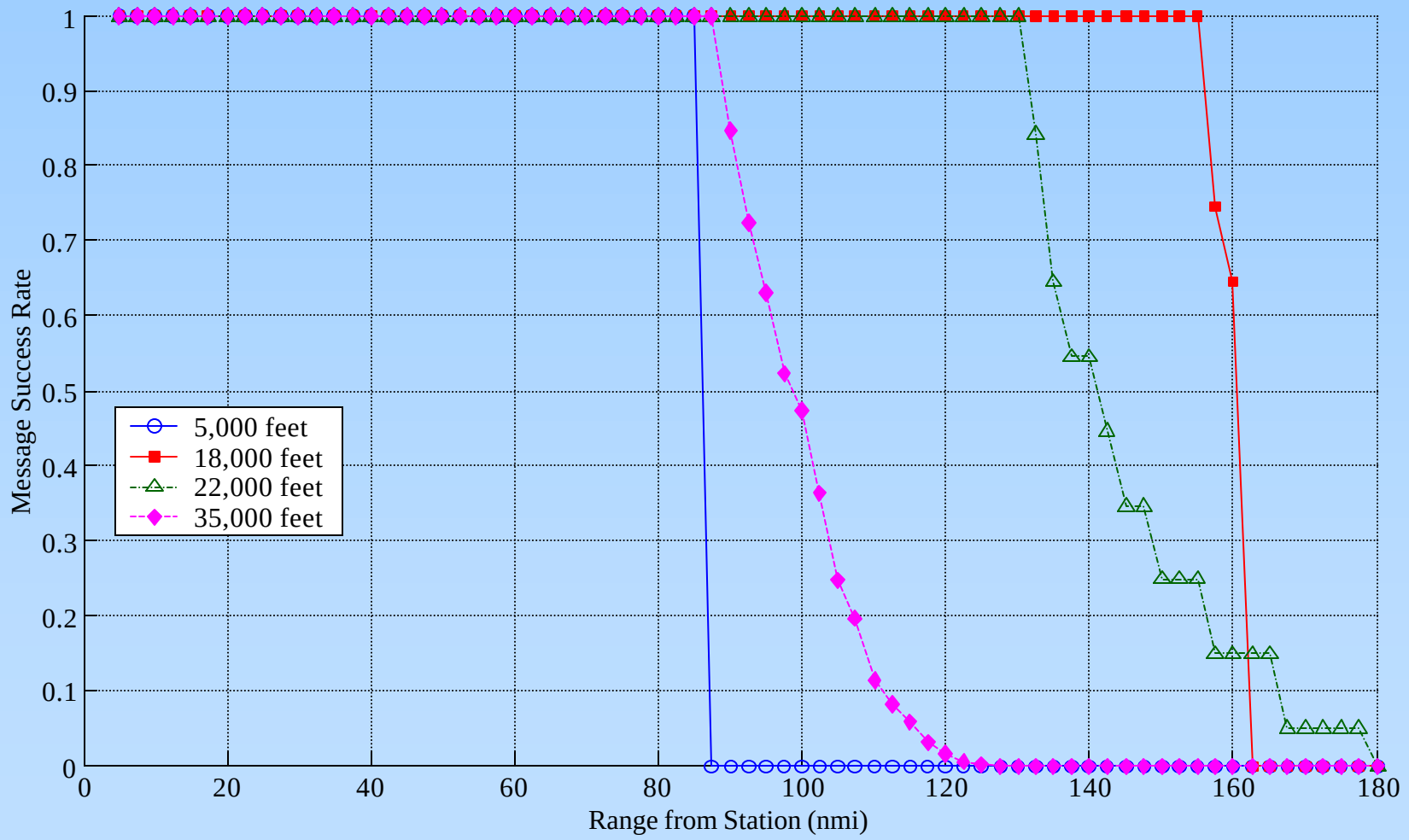
- FIS-B uplink performed in protected slots where no ADS-B transmissions exist
- 7-cell reuse pattern
- Sources of Interference
  - Other VDL4 ground-based transmitters (GBTs) in the same slot



VDL Mode 4 Simulation Results for 60 nmi grid



VDL Mode 4 Simulation Results for 120 nmi grid



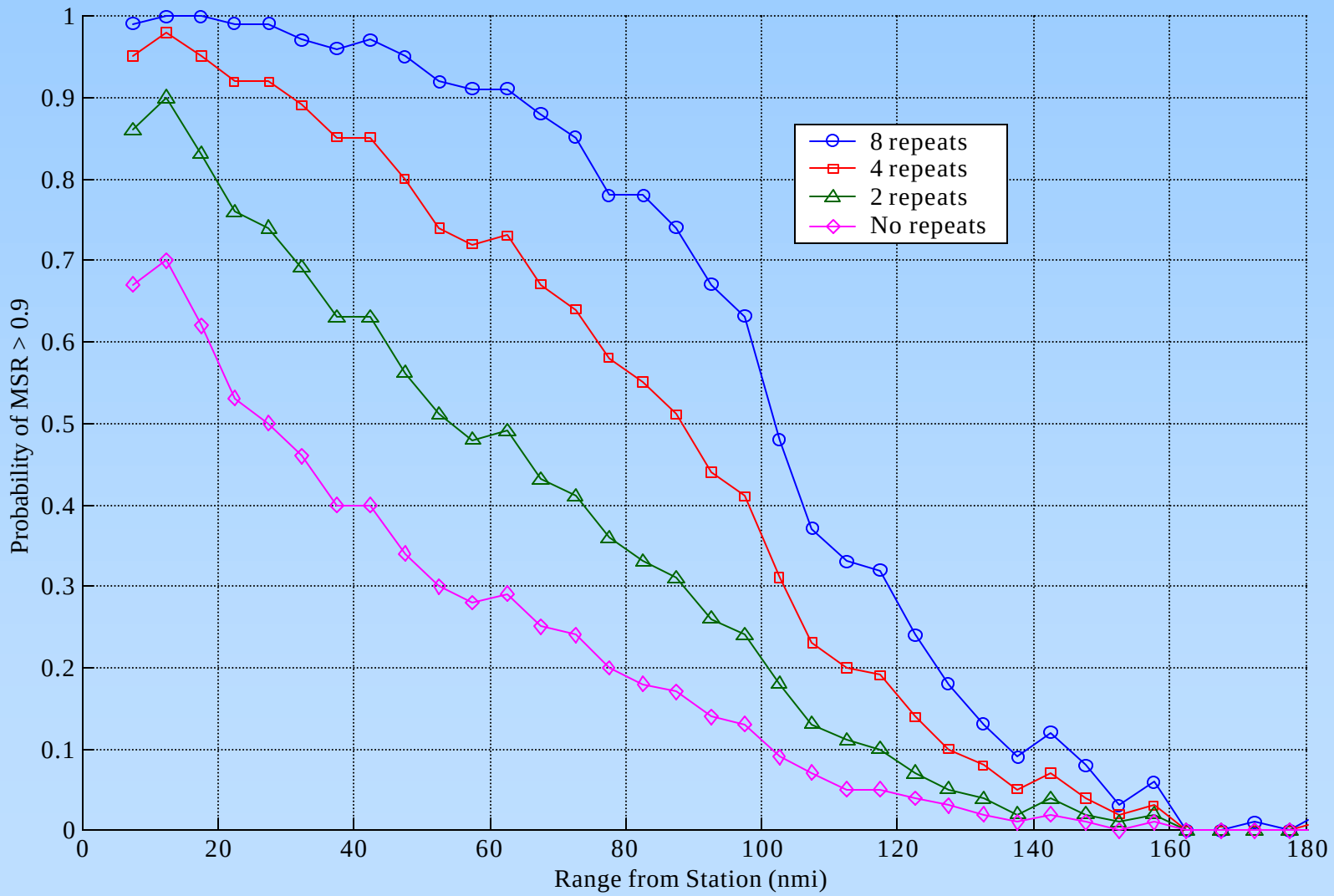
Bounding FIS-B Capacity on VDL Mode 4

- VDL Mode 4 achieves full coverage for the 120 nmi grid – a receiver anywhere in the grid all messages with at least 90% MSR
- Lower bound in bps
  - $N_{rs}/N_{cell} * 192$
  - In this study $N_{rs} = 4$, $N_{cell} = 7$,
  - throughput =110 bps
- Upper bound is set by a FIS-B channel
  - 14.4 kbps/ N_{cell}
  - Throughput max would be approximately 2100 bps

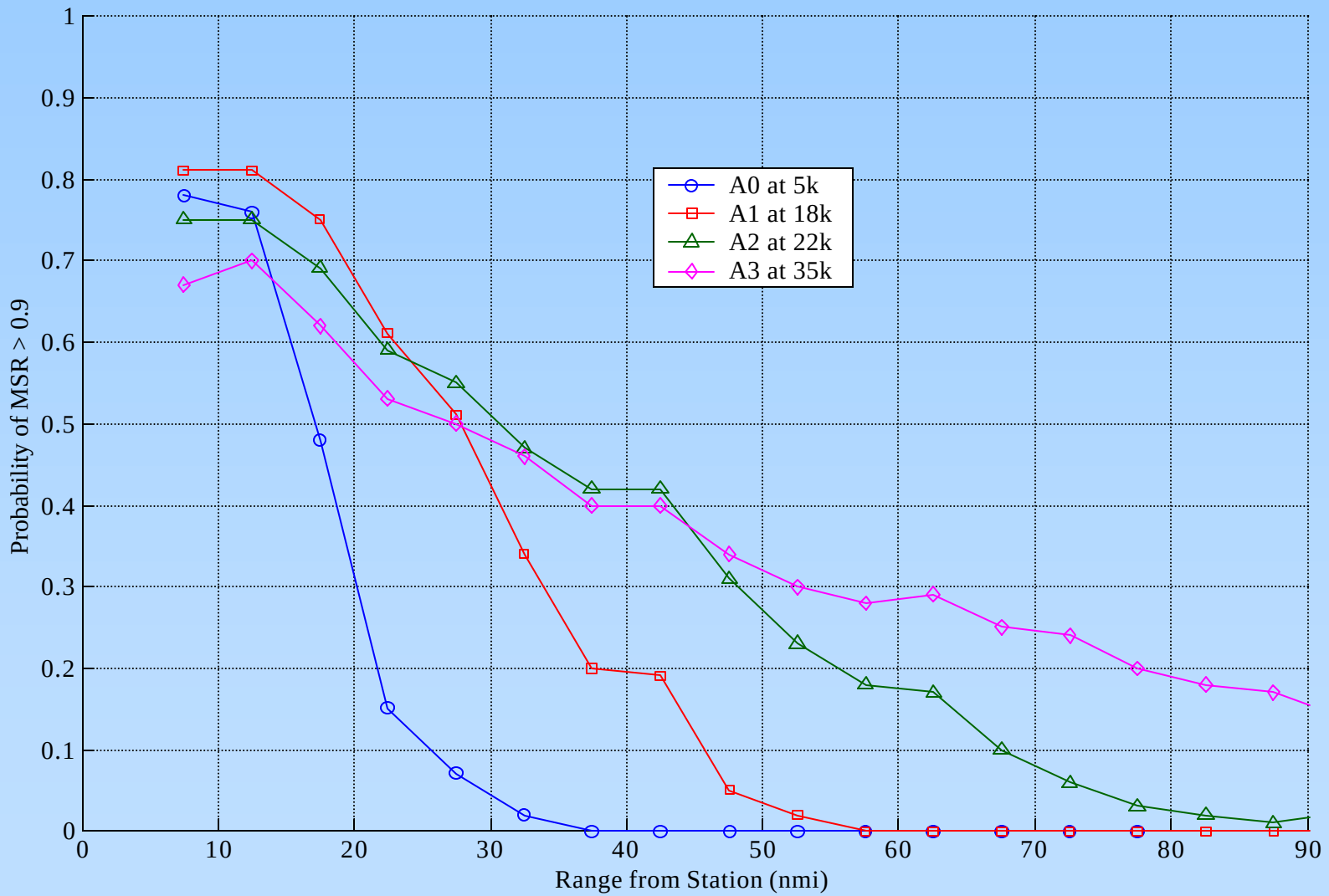
FIS-B on Extended Squitter

- Random Access Transmissions – no reuse
- 10 FIS-B squitters per second per ground station
- Sources of Interference
  - Extended squitter GBTs
  - ATCRBS
  - Mode S
  - TCAS interrogations and replies
  - ADS-B messages
  - Co-site transmissions (on-board DME, ATCRBS, TCAS, Mode S)
- Receiver located 70 nmi outside LA
- Various message resend patterns used

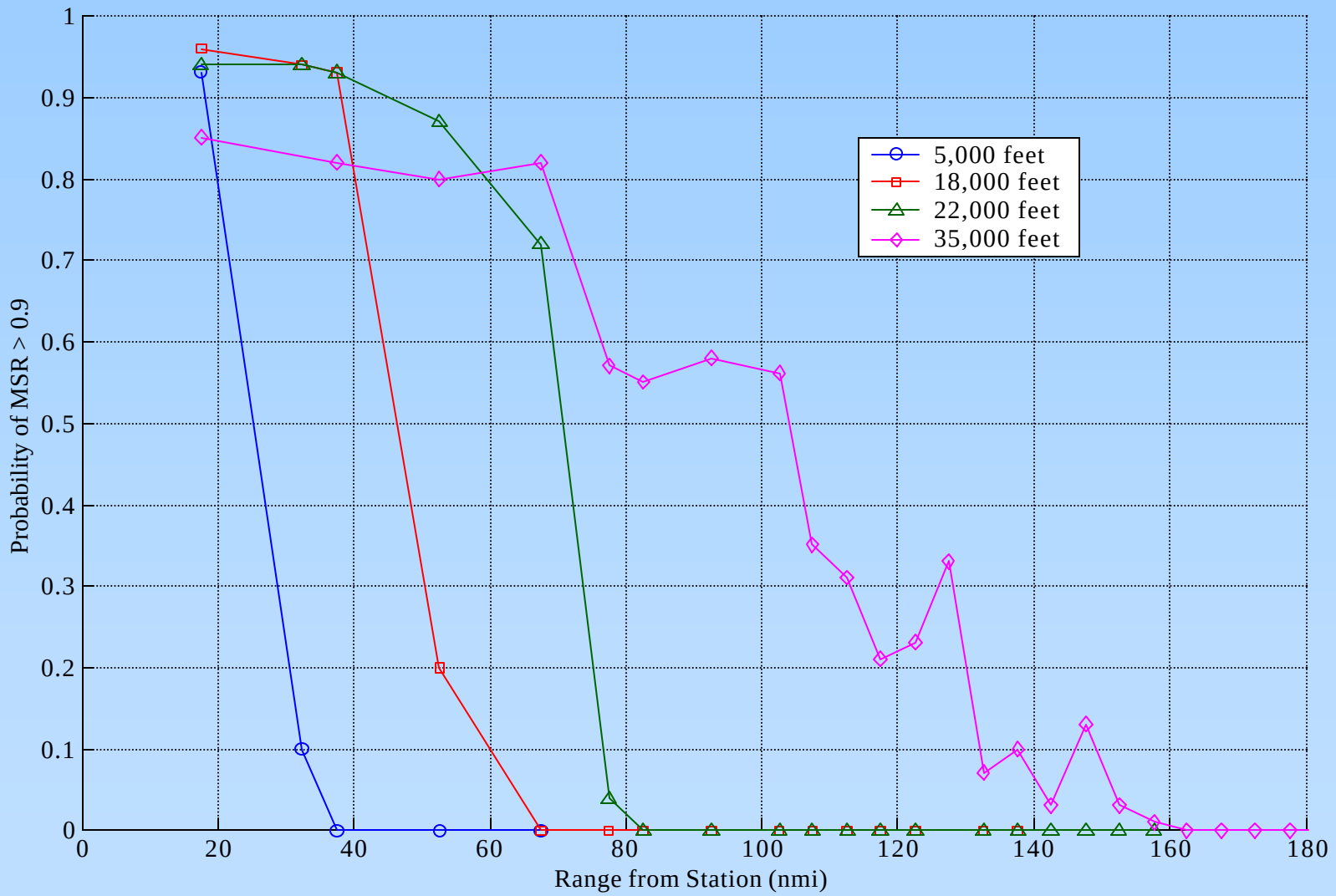
Effect of Repeating Messages on 1090 – for A3 at 35k on 120 nmi Grid



Extended Squitter Simulation Results for 60 nmi Grid – No Repeats



Extended Squitter Simulation Results for 120 nmi Grid – No Repeats



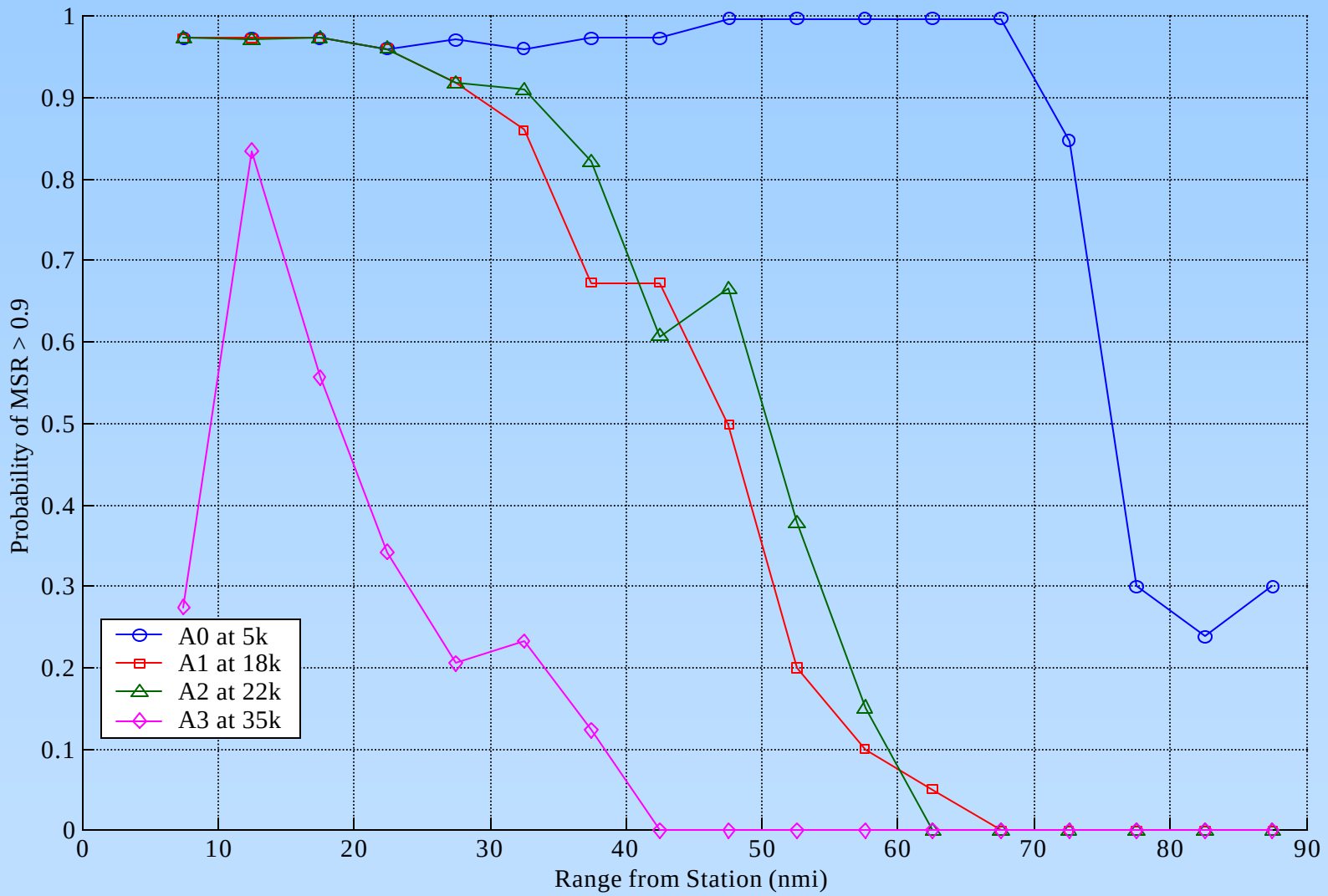
Capacity Estimate for Extended Squitter

- Extended Squitter system performs better in 60 nmi case
- Repeating messages can improve individual MSRs, but doesn't significantly extend range
- Performance is better at higher altitude / higher equipage class
- Capacity estimate
  - 1x redundancy, throughput = 88 bits * 10 squitters / sec = 880 bps

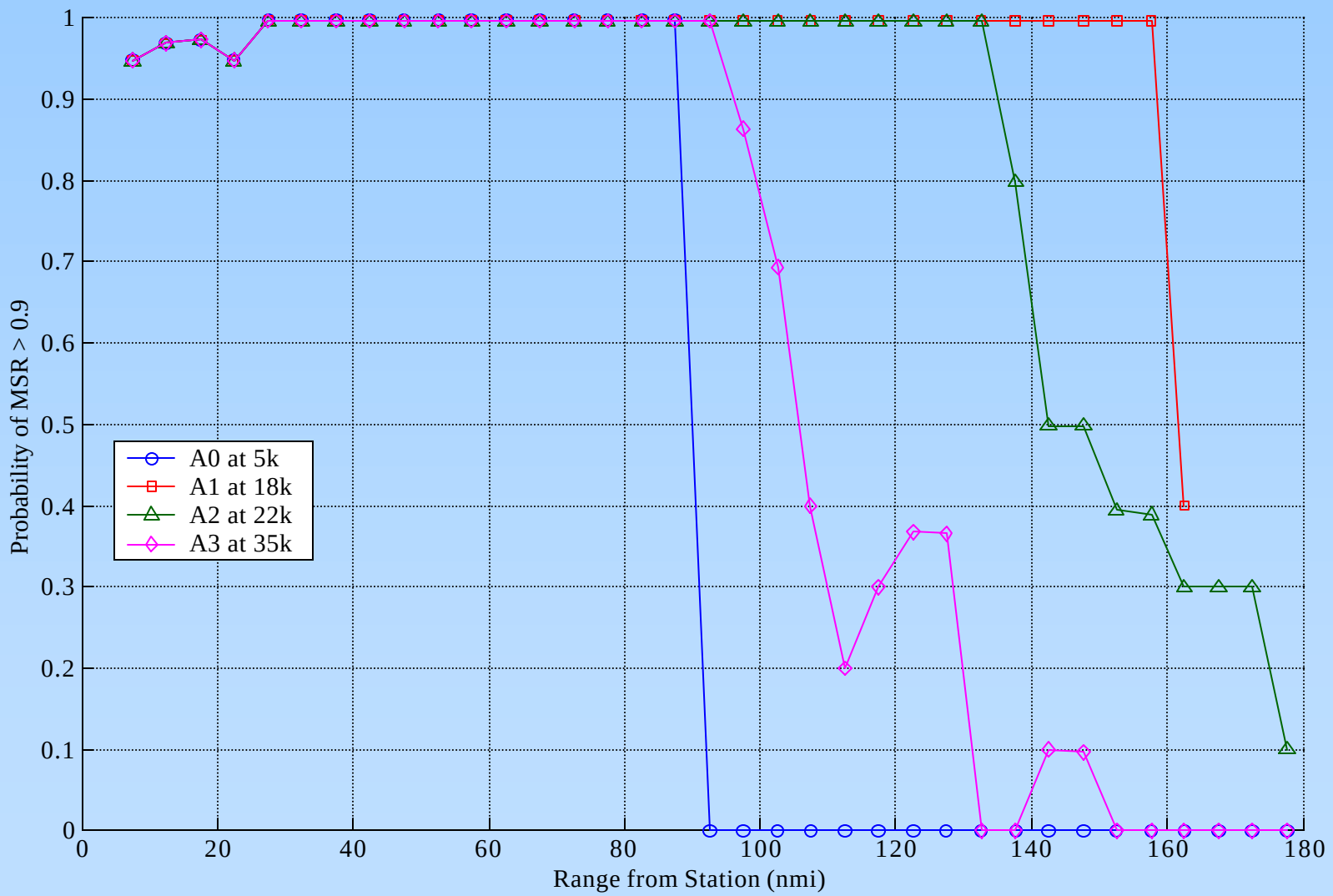
FIS-B on UAT

- Uplink occurs in protected time, no ADS-B interference
- Interleaved Reed-Solomon (92,72) encoding
- 3.45 kbit data in uplink message
- Sources of Interference
  - Other UAT GBTs
  - Co-site transmissions (on-board DME, ATCRBS, TCAS, Mode S)

UAT Simulation Results for a 60 nmi grid



UAT Simulation Results for a 120 nmi grid



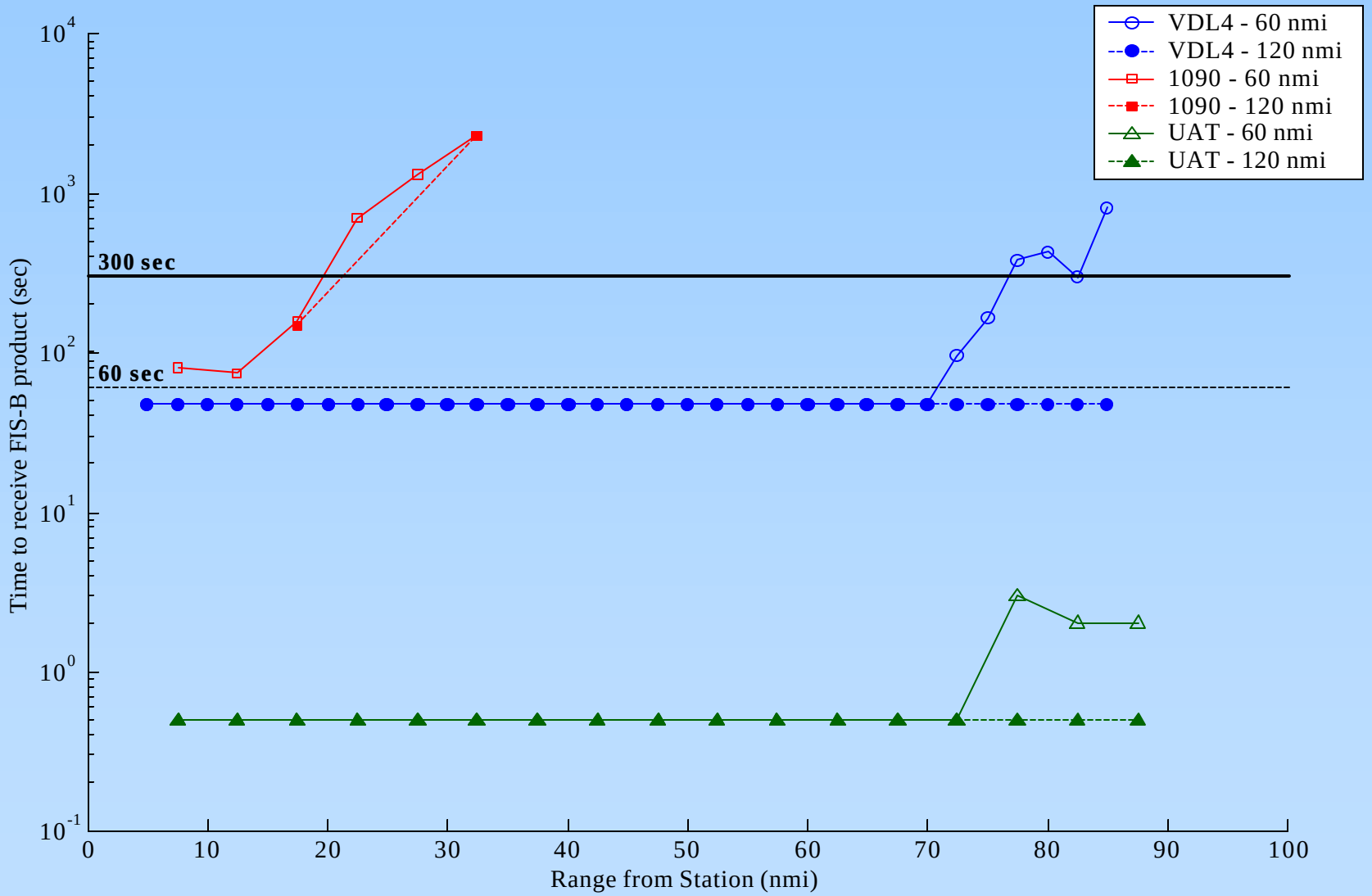
Capacity Estimate for UAT

- UAT achieves full coverage in 120 nmi grid – a receiver anywhere in the grid can receive 90% of the messages with at least 90% MSR
- 32 slots in each second for ground based transmitters to broadcast
- 7 cell-reuse pattern (28 of 32 slots used for FIS-B) gives 13,824 bps throughput

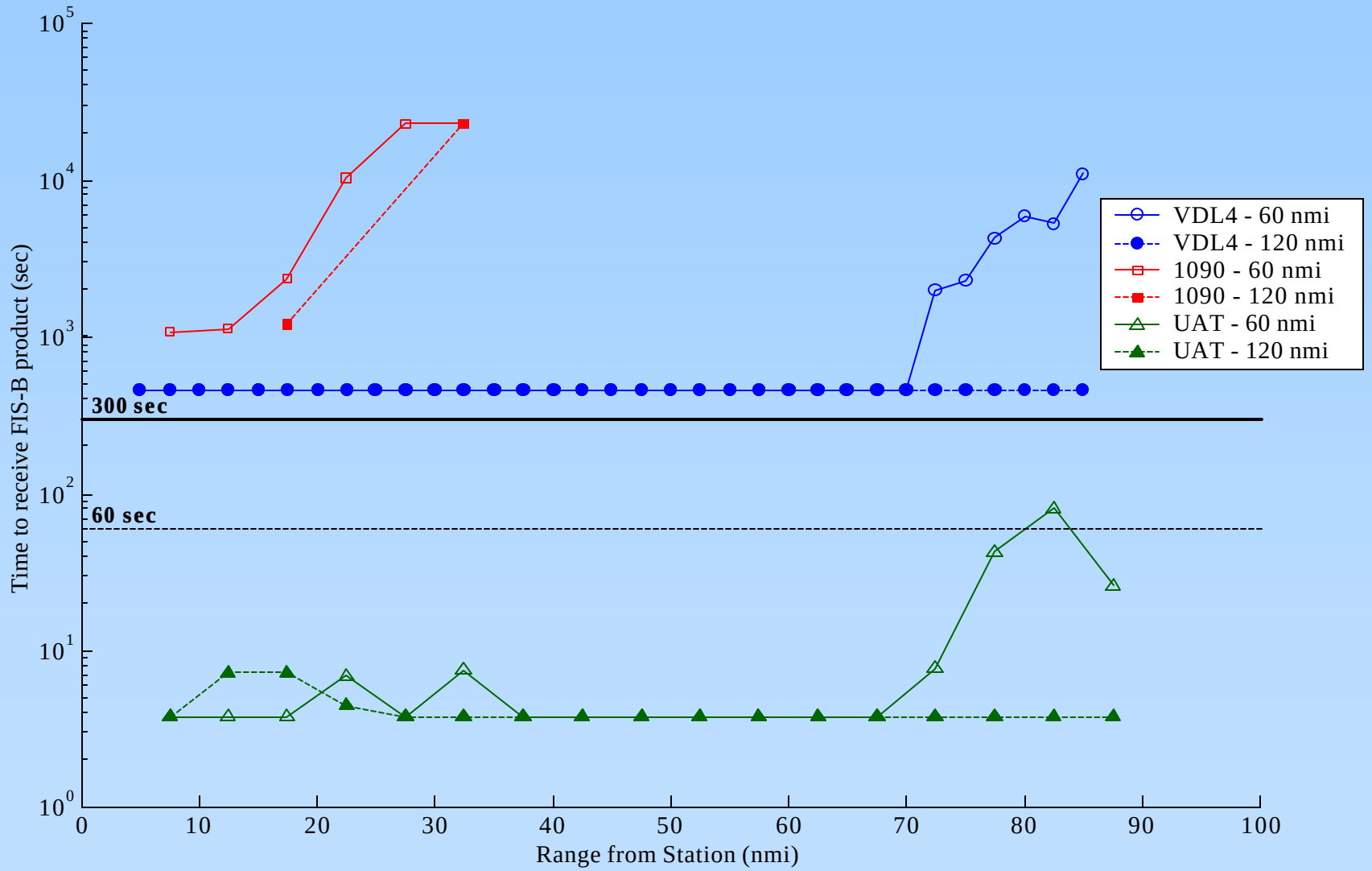
Time-to-Deliver

- Loop over unique messages required for product delivery (different for each link)
  - Message received? – Random draw against probability to get message with > 90% MSR
  - Check to see if all messages have been received
  - Calculate time to deliver all *N* unique messages
- Run 100 trials and take average time to smooth out statistics
- Plots include update rates cited in RTCA DO-237
  - 1 minute line for ‘terminal area’ data
  - 5 minute line for ‘national/regional’ data
  - Composition of ADS-B FIS-B products (and hence the required update rate) depends on architecture employed

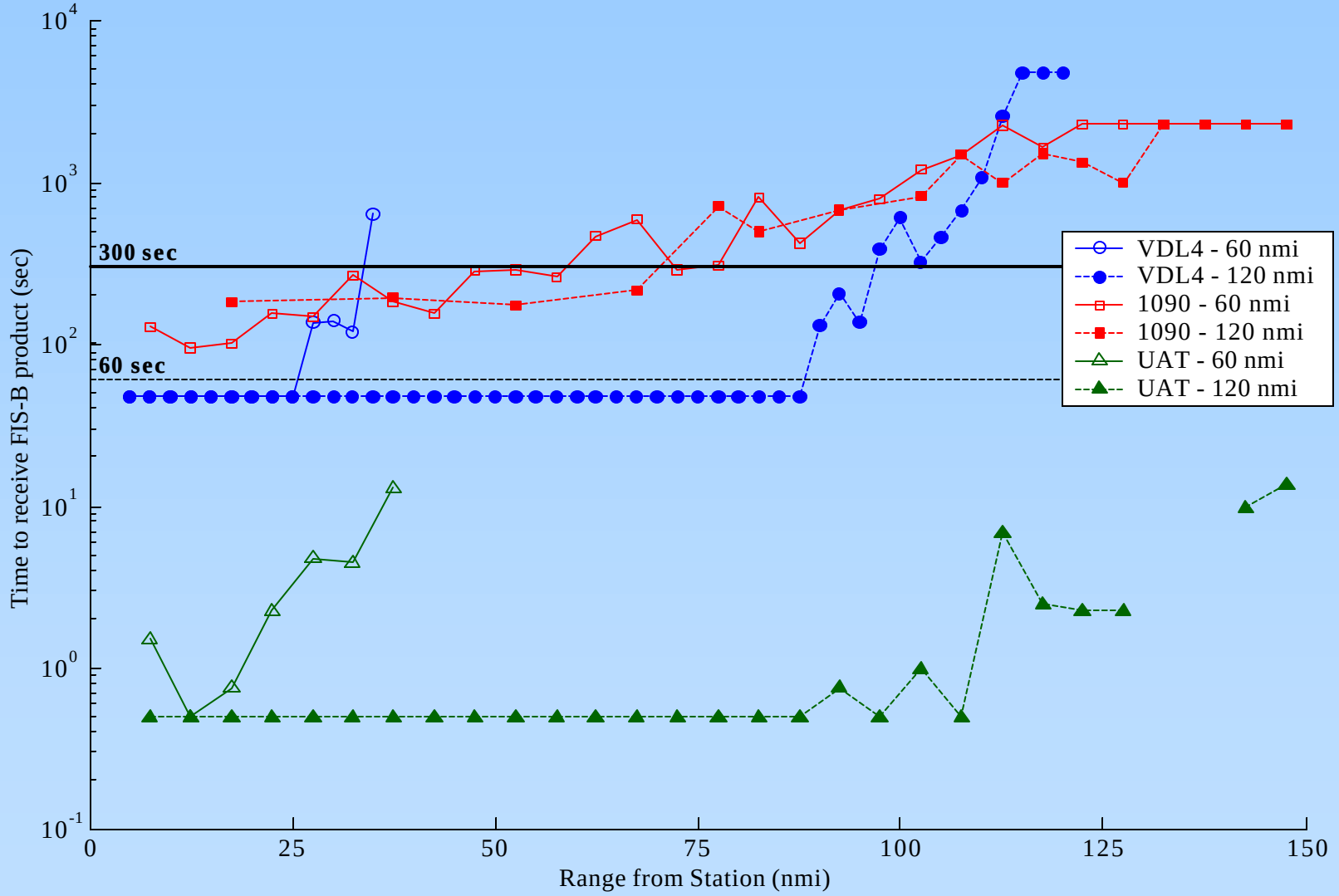
Time to Deliver 5 kbit Data with 90% MSR to A0 equipage at 5,000 feet



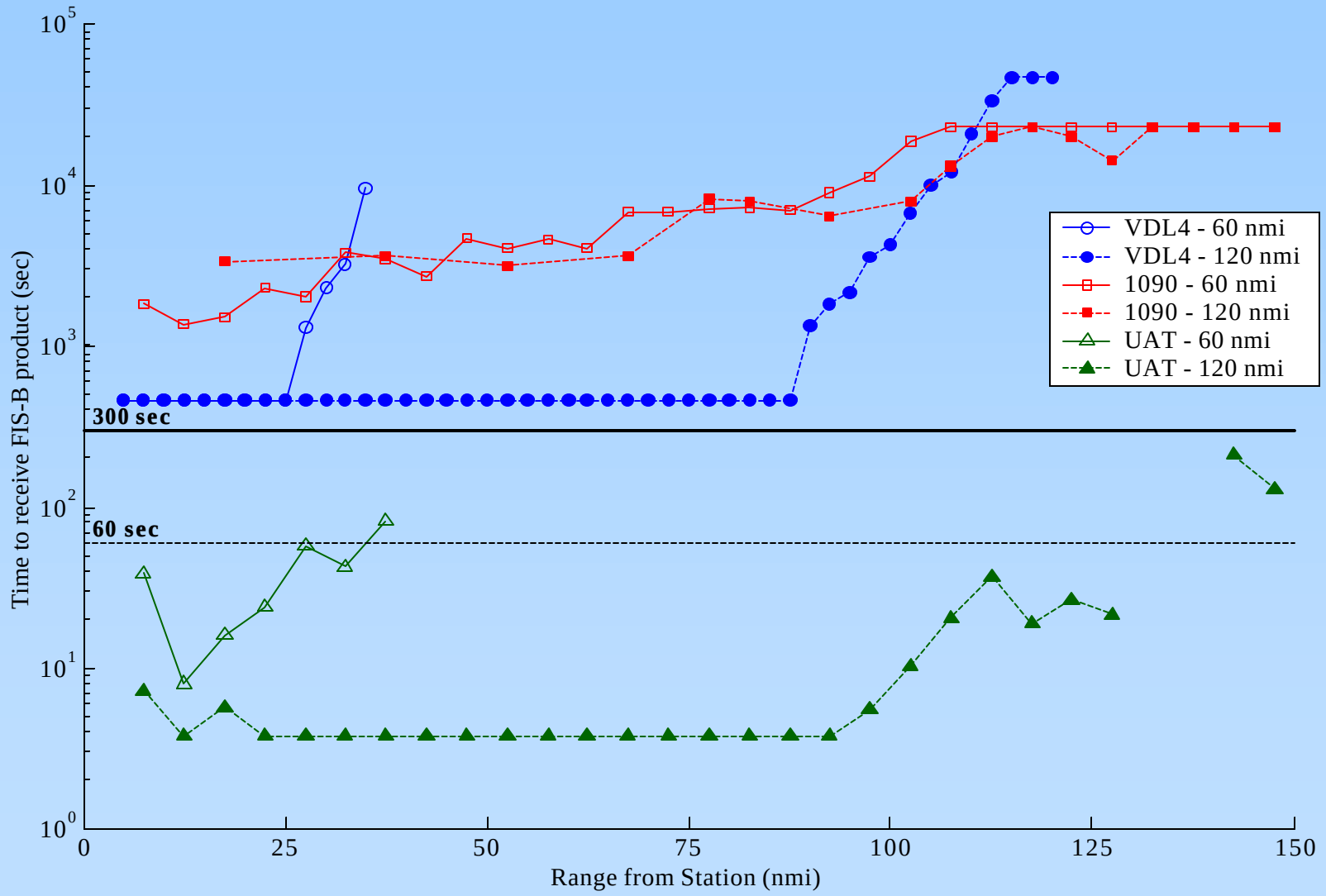
Time to Deliver 50 kbit Data with 90 % MSR to A0 equipage at 5,000 feet



Time to Deliver 5 kbit Data with 90% MSR to A3 equipage at 35,000 feet



Time to Deliver 50 kbit Data with 90 % MSR to A3 equipage at 35,000 feet



Summary of Results

- Time to deliver a 5 kbit data set:
  - UAT and VDL-4 meet 60 second requirement for both A0 at 5,000 feet and A3 at 35,000 feet
  - 1090 can provide data to A3 at 35,000 feet within 5 minute update requirement but cannot to an A0 at 5,000 feet
- Time to deliver a 50 kbit data set:
  - UAT can deliver data in under 5 minutes
  - VDL – 4 as configured here does not meet 5 minute requirement – could increase number of reserved slots, but this would decrease ADS-B bandwidth
  - 1090 does not meet the 5 minute requirement as configured
- Time to deliver FIS-B data scales with size of the product for all three links

Functional Definitions of Interactive ADS-B Equipage

- A0 (Minimum interactive capability) broadcast ADS-B messages are based upon own-platform source data. ADS-B messages received from other aircraft support generation of ADS-B reports which are used by on-board applications
- A1 supports all class A0 functionality and additionally supports ADS-B-based conflict avoidance. Class A1 is intended for operation in IFR designated airspace.
- A2 supports all class A1 functionality and additionally provides extended range and information processing to support optimized separation applications. This service requires the broadcast and receipt of intent information contained in TS and TC+0 reports.
- A3 supports all class A2 functionality and additionally supports flight path deconfliction. Class A3 subsystems support longer look-ahead times with longer operational ranges than class A2. Class A3 has the ability to broadcast and receive multiple TC reports.